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Naval Recommendations for DMA's Prototype Tactical Terrain Data

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Executive Summary:

The Tactical Terrain Data (TTD) will be utilized by the U. S. Navy and the U. S. Marine Corps to support various tactical terrain systems and applications, including Mission Planning for Strike Warfare, Amphibious Area Land Management, Communications for Command and Control, Intelligence Data Fusion, and Maneuvering and Fire Support for Command and Control. The Marine Corps will depend directly upon TTD for enhancement of intelligence information to support battlefield operations. The Navy will utilize the TTD for support of amphibious and near-shore operations, as well as facilities engineering and management.

The Navy and the Marine Corps are committed to using TTD in support of naval operations involving amphibious and near-shore tactical support. The capability of this data to provide reliable digital terrain information in a format that is usable for naval operations depends greatly upon the Navy's ability to define its long-range terrain data requirements. This naval evaluation of TTD is intended to specify these requirements, to identify deficiencies within the prototype product, and to make formal recommendations to the Defense Mapping Agency (DMA) on data product improvements, which will ensure optimum support of naval requirements. This report concentrates upon examination of the TTD for its data content, accuracy, resolution, and structure with reference to stated Navy/Marine Corps digital terrain information requirements. The Navy's evaluation of TTD is being conducted by the Naval Digital Mapping, Charting, and Geodesy Analysis Program (DMAP) located at the Naval Ocean Research and Development Activity (NORDA), and is sponsored by the Oceanographer of the Navy, Chief of Naval Operations, CNO OP-096 under PE 63704N Project R1987. This paper has been approved for public release.

Background Information :

The Naval DMAP is conducting its examination of the Tactical Terrain Data within two phases of evaluation. Phase I has been completed and was designed to identify Navy and Marine Corps requirements for TTD, and to manually examine the initial TTD data specification. Phase II is intended to concentrate more on utilizing digital analysis techniques to determine TTD's effectiveness at addressing the applications identified within Phase I. Phase I of the Naval DMAP evaluation was begun in October 1988 with an initial review of the prototype product specification. Recommendations were presented to U. S. Army Engineer Topographic Laboratories (ETL) in an interim report submitted in January 1989.

The primary purpose of the phase I evaluation was to familiarize Naval Commands with the TTD data set and to assist them in identifying their long-term requirements for digital terrain information (DTI). The results of this phase I evaluation indicated that the Navy and the Marine Corps do have substantial requirements for DTI and that the TTD prototype demonstrates an adequate level of support for these information requirements. Although DMAP's Phase II evaluation began in January 1989, no major digital manipulation of TTD by DMAP has occurred. At present, DMAP is completing efforts to implement TTD within NORDA computer environments and will begin an in-depth technical digital evaluation of the data set as soon as these efforts are completed. The Naval DMAP has acquired both the Geographic Resources Information Support System (GRASS) and Air Land Battlefield Environment System (ALBE) Geographic Information System (GIS) packages to support these efforts.

Test-Bed Environment:

Program Name

Naval Digital Mapping, Charting and Geodesy Analysis Program (DMAP)

Assisted by:
Naval Civil Engineering Laboratory (NCEL)
Port Hueneme, California

U. S. Marine Corps Research and Development Acquisition Command (MCRDAC)
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Hardware/Software Description

VAX 11/780-VMS 4.7
Tektronix 4208 Graphics Monitors
Air Land Battlefield Environment System (ALBE) software

Macintosh II A/UX-UNIX 1.1
E-Machines 1024 x 808 High Resolution Monitor
GRASS GIS

Sun 1/360-Unix
High Resolution Color Graphics Monitor
GRASS GIS software

Level of Effort

NORDA-One DMAP person, allocated 1/4 man-year

Description of Target Systems:

Amphibious Objective Area Land Management System (AOAMS)
Assists in site selection and development, trafficability, and mobility analysis for tactical amphibious operations
Currently fielded:
TTD required by FY92, usable if delivered sooner.

Tactical Intelligence Management System (TIMS) supports intelligence Data Fusion for tactical combat operations.
Under development (FY 90 operational):
TTD by FY 92, usable if delivered sooner.

Other applications:
Communications for Command and Control
Maneuvering and Fire Support for Command and Control
Mission Planning for Strike Warfare

Major Evaluation Aspects:

To date, only nonautomated examinations of the TTD data set have been conducted by the Naval DMAP. DMAP is currently working to bring the TTD up in three separate environments: Zenith Z-248, Macintosh II/GRASS GIS, and the VAX 11/780/ALBE-MOSS/MAPS GIS. Once operational within these environments, DMAP will continue its evaluation of TTD relative to Navy and Marine Corps requirements for digital terrain information.

Accuracy

The 1:50,000 scale topographic line map (TLM) of Fort Hood, Texas, was used as a collection base in the manual compilation of the prototype data set. Subsequently, all data layers stored within

the integrated TTD data set are based upon this scale. Review of Navy and Marine Corps applications for TTD indicates that the product's base scale of 1:50,000 adequately supports most naval output requirements for digital terrain information. However, there are specialized applications which could greatly benefit from a higher level of accuracy. These applications include trafficability and mobility analysis-type operations.

TTD has a stated **vertical accuracy** of ±20m at 90% linear error to Mean Sea Level. This accuracy also appears to be adequate for most naval applications of digital terrain information. However, it seems that in the case of applications that rely upon the Digital Terrain Elevation Data (DTED) Level II data stored within TTD, the vertical accuracy of TTD must be stated in direct relation to the vertical accuracy of the DTED Level II used within the prototype data set. DTED Level II has a stated vertical accuracy of ±30m with 90% assurance. This level of vertical accuracy may not be fully adequate in relation to the stated applications.

Horizontal accuracy for TTD is stated as ±50m at 90% circular error. This accuracy adequately supports most applications of digital terrain analysis, including trafficability, mobility analysis, and site selection. For some applications of fire support and targeting information, greater accuracies could prove to be of benefit. At present the Navy and the Marine Corps have not identified any TTD applications that would require a horizontal accuracy greater than ±50m. Targeting and fire support applications, which require a greater level of accuracy, would rely upon other data sets designed to directly support these applications.

Resolution

The data density of TTD varies with the actual density of depicted features. Normally the resolution is comparable to that portrayed at 1:50,000 scale on topographic line maps, terrain analysis factor overlays, and combat charts that are digitized to comprise the TTD feature information. Since much of the data stored within TTD is center-line, both the presence and absence of information must be considered to comprise the overall data resolution. Thus, the resolution of the DTED Level II information can be used to illustrate the overall resolution of TTD. If used as raster information, TTD can be displayed at DTED Level II-type resolutions of 30m. However, this type of rasterization of the data base eliminates the usefulness of the MiniTopo data structure and may not be appropriate for some applications. These types of data operations are discussed further within the data structures section of this report. At present, the current resolution of the TTD feature data sets seems to be sufficient for naval applications.

Content

The Tactical Terrain Data contains three-dimensional feature data that depicts the elevation, or "z" values, of the individual features. In addition to a DTED Level II data cell, which accompanies each data file, TTD consists of eight individually digitized feature layers that include surface configuration (slope), surface materials, vegetation, obstacles, special features, transportation, surface drainage, and urban areas. These data layers are then combined to form an integrated TTD data set. The content level of TTD must be reviewed on an individual application basis to determine if the feature data contained within TTD is adequate to support Navy and Marine Corps requirements. In doing so DMAP has determined that the TTD data content is adequate to meet the base-line requirements of support to all presently identified naval applications. It is noted that amphibious applications would be better served by TTD that contains both shoreline and shallow water bathymetry data. DMAP also notes that the content of TTD is further facilitated by the option of value-added data that can be input at the user level.

Navy's primary concerns for TTD data content currently lie within the area of the Feature Attribute Coding Standard (FACS). At present, the FACS does not adequately support the definition of beachfront and shoreline characteristics. Although the Navy has emphasized this requirement for some time, it has also experienced some difficulty in reaching agreement as to how these features should be entered into a digital format. One commonly accepted definition for these features is as follows. Beaches can be divided into three major regions: nearshore, foreshore, and backshore (Schwartz, Maurice L., Encyclopedia of Beaches and Coastal Environments, Hutchinson Ross Publishing Co., Stroudsburg, PA, 1982, pp. 528-529). In addition to the lack of an adequate definition for shoreline, the FACS also does not support the adequate representation of other coastal features, such as a berm, beach ridge, and washover fan. In order for the TTD to adequately display coastal zone information to support tactical amphibious naval operations, the FACS must be updated to support this information.

In addition to the lack of beach information, the location of the current TTD prototype does not offer a true representation of digital tactical terrain information encountered in tactical amphibious naval operations. The lack of coastal features within the Fort Hood area leaves a serious void in the prototype data set's capability for fully demonstrating digital terrain data analysis requirements of the Navy.

In review of the overall content of TTD relative to naval applications, the Naval DMAP submitted the TTD Content Overview Matrix (Micro Level), developed by U. S. Army ETL, to each

evaluation participant. All TTD data themes were found to have some naval significance. The following comments are included to further describe the significance of the data content of TTD and to emphasize that these elements should remain in the data set.

Slope: Slope Polygon Ranges of >15 and < or = 98% are useful in determining cross-country mobility models. Although this information is excessive from the naval civil engineering standpoint, it is viewed as significant to mobility analysis and troop-movement scenarios.

Surface Material: Tree spacing and predominant vegetation height ranges are critical to tactical terrain operations. The greater precision data currently available in TTD will support mobility models and more intense visibility and line-of-sight models.

Surface Drainage: Needed for trafficability models

Vegetation: Data specifying vegetation type, ground cover and obstacles are significant to trafficability models.

Transportation: Road conditions and categories further support trafficability analyses. Load classes are also significant to mobility models.

Obstacles: Significant utility for cross-country mobility analysis.

Urban Areas: Significant utility for mission planning.

Special Features: Many features within aircraft facilities seem to be redundant (i.e., helipad). Many urban special features (i.e., drive-in theater, parking lot, etc.) can be useful for tactical operations, such as a helipad. This information is good to have and should be maintained.

Structure

Integrated/Non-integrated TTD Product Justification: The use of an integrated TTD product will require a substantial amount of overhead for data handling and processing operations within most naval applications. All applications currently identified by Navy and Marine Corps utilize specialized software and data processing subsystems that are not designed to handle the intensity or complexity of spatial data provided within the integrated version of TTD. In addition, public domain GIS software currently being used to support naval applications is oriented to handling spatial data on a thematic basis. Many of the query routines within these systems are designed to extract information relative to the manner in which that particular system has overlayed the data, and further support merging the data layers within a data handling subsystem.

The delivery of TTD as an integrated data set will most often restrict the way in which these systems can utilize the terrain information.

In addition, many naval applications utilize a low-end computer environment (i. e., IBM AT compatible) for their operational platform. The integration of this data set would also place additional time and memory constraints on these systems. In many instances, the applications may require a minimal level of support from TTD, and the overhead of handling the integrated data would thus require substantial transformation of the TTD data set to meet these system requirements. In most system scenarios, only a few of the eight TTD data themes may be required to produce a desired output product. By providing the TTD within the non-integrated format, the user will be able to more readily extract only the information with which he is directly concerned.

MiniTopo: Advantages/Disadvantages - The Naval DMAP has reviewed the data structure specifications for TTD to determine its ability to adequately support naval processing of digital terrain information. The MiniTopo data structure is designed to serve as DMA's internal data structure for transferring cartographic and digital spatial information within the Mark 90 production environment. Some features of the structure may not be advantageous to a spatial data analysis environment. DMAP's evaluation of the TTD data structure examines factors relative to data's storage, spatial relationships or topology, and data exchange formats. Each of these factors are examined below.

Data storage: A spatial data structure must be capable of storing both descriptive and geometric cartographic information. The MiniTopo appears to offer an effective means of doing so. Although some elements appear redundant, the overall structure offers a systematic approach to handling both of these elements.

Topology: An important concept to maintain within the structure is the capability to selectively utilize the topology within the structure. Most naval systems currently do not have the software capability to handle these items. Designing the data structure in a manner that allows these elements to be easily stripped off facilitates the data's use within these systems, as well as more complex, topologically oriented GIS environments.

Digital Exchange Standard: The development of digital cartographic data standards is viewed by many as an effective means of enhancing the capability of geographic information systems and specialized tactical information systems to share and utilize the myriad digital data resources available. Through attribute coding standards and common topological data structures, these systems are able to exchange data in a form that is more readily manageable. The use of these standards in conjunction with digital media

standards, such as those for the Compact Disk-Read Only Memory (CD-ROM), offers substantially improved methods of exchanging digital Mapping Charting & Geodesy information.

The Naval DMAP recognizes substantial benefit in the development of these standards and applauds the efforts of such groups as the Federal Interagency Coordinating Committee on Digital Cartography (FICCDC) and the National Committee on Digital Cartographic Data Standards (NCDCDS) for encouraging their standards development. However, it is also recognized that the overall benefits to both the data producer and user must be weighed when determining the feasibility of using these standards.

The TTD prototype and future production versions of the data set are being delivered within the constraints of the ISO-8211 and Spatial Data Transfer Specification (SDTS). Together, these descriptive specifications are designed to offer a concise and improved mechanism of transferring digital spatial data between computer system environments of differing types. In its entirety, this exchange mechanism is designed to provide an environment in which digital data can be fully described and formatted with record identifiers and tagged field delimiters. This mechanism should greatly benefit the data recipient who may have very limited knowledge of the characteristics of a transferred data set. The ISO-8211 and SDTS are intended to provide this flexibility of data transfer by offering a way to readily describe the individual cartographic and spatial features of a digital data set. The intent of this data specification is to provide the data recipients with a "dictionary" that describes the features and information being transferred to them, thus improving the usability of this data and eliminating most of the need for additional contact with the data sender.

Although the intended concepts of ISO-8211 are commendable, the Naval DMAP has recognized no substantial benefits to the DoD user community from DMA's use of these transfer specifications in delivering the TTD prototype. In fact, its use within this context appears to intensify the work required by the data recipient prior to actually utilizing the data product. Two primary factors have adversely influenced DMAP's attitude on delivering TTD within the constraints of ISO-8211:

A complete specification of the data product is already provided by DMA and is designed to fully describe the data elements and structure of the data, and

Current use of ISO-8211 does not support direct access of the data and, in fact, sacrifices the optimum use of CD-ROM digital transfer media.

The present use of ISO-8211 for delivering TTD requires that the data user become knowledgeable of both the prototype data

specification and ISO-8211/SDTS: When the data set is imported from the ISO-8211 environment, the data are not restored to their original form, so the user must decide either to utilize the additional information provided by the transfer specification, or to develop additional input software that removes this extra information: only then can the data be accessed according to the original data specification. In its current form, the use of ISO-8211 eliminates the CD-ROM as a direct access media. Since the ISO-8211 data files must be imported using a routine that writes a new data file, the user is forced to use other storage media to hold the imported data files. For many low-end systems, i.e., Zenith Z-248, this represents a tremendous waste of this media.

An additional frustration of the current prototype is that the data are delivered entirely as ASCII character data. Although this feature may improve the user's visualization of the data, it is considerably more demanding of both storage space and i/o processing than the transfer of binary data files. If ISO/8211 were used to transfer a highly compressed, very difficult to read data format, it would have some redeeming qualities. All of the current DMA databases are being developed with ease of readability and data transfer as an important factor and have already greatly sacrificed efficiency in terms of storage space, ease of direct use, and speed of access.

Applications:

Intended Uses

As indicated, TTD will serve the U. S. Navy and the U. S. Marine Corps as a tactical planning data base in support of naval amphibious operations. The intended uses of TTD within naval applications will be to provide mission planning and operational support to naval forces in executing amphibious warfare operations. TTD will support naval commands in determining optimum landing zones for tactical amphibious landings, and will be used to plan and implement tactical naval warfare strategies for operations for beach zones and terrain within 3-5 km range of a amphibious beach-landing zone. It is feasible that TTD could be installed on naval vessels and within marine command posts to develop and support tactical decision aids for all phases of naval amphibious warfare.

The type of system and hardware that will utilize the TTD may vary considerably depending upon its intended use and output. Most systems will not fully utilize the entire TTD data set; however, it is expected that a limited tactical amphibious GIS will be established to take advantage of the myriad information stored within TTD.

Applications Matrix

Attachment 1, Naval TTD Applications Matrix, was developed using responses from NCEL and MCRDAC representatives.

Transformations:

At present, no specific transformations have been identified as necessary for any Navy or Marine Corps systems to utilize the TTD. This identification will be a focus of DMAP's Phase II TTD evaluation. However, MCRDAC has identified the potential for some data transformations to support specialized systems. These potential transformations are not identifiable at this time, but are expected to become more apparent as MCRDAC uses the prototype more extensively. Transformations will remain a major focus of DMAP's continued evaluation and use of the TTD.

Concerns:

The Naval DMAP has direct concerns over the use of ISO-8211 as the exchange mechanism for TTD. Given our past experiences with this transfer specification, we feel that in its current form ISO-8211 is an inappropriate mechanism in which to deliver the TTD data set to the end user. It is understood that DMA has elected this environment as an internal exchange format to accompany its Mark 90 internal data structure, MiniTopo. DMAP recognizes the advantages such a transfer specification can provide to a large-scale data production facility; however, it is felt the end-user requirements should be the driving force in determining how DMA data bases are to be transferred.

An additional concern in using any transfer mechanism that does not support direct access of TTD according to its original data specification is that the CD-ROM media loses its potential as an on-line direct access media. Data provision within its original structure, i. e., MiniTopo, would provide an excellent means of utilizing this large capacity media for direct access. Additionally, the current practice of transferring TTD within an ASCII character format, as opposed to a binary data format, increases the amount of storage required for the data. Since the ASCII format is intended to facilitate visualization of the data file, ASCII dump routines could be included with a binary data set to eliminate a sizable portion of the data file size. Directory structures and programs to access the data directly in its binary or compressed format would be more beneficial to the DoD user than the use of ISO-8211.

The TTD data set is an extremely large data base. The integrated prototype alone comprises over 40 megabytes of storage for a geographic area of 15 minutes latitude x 15 minutes longitude.

Many TTD applications could require data sets that cover much greater areas. The current size will be a continued limitation to how big an area of interest an application system can work with at a given time. The use of data compression routines similar to those being utilized for the World Vector Shoreline and other standard data products could assist in greatly decreasing the size of a TTD data set.

DMAP also recognizes many potential end-user difficulties in using the TTD as an integrated data set. The use of a compressed data set, and the provision of indexing and read routines to access only the desired features might eliminate many of the problems encountered with using the integrated data set. The advantages of an integrated data set would not be fully utilized by the majority of DoD systems, and would most often force users to develop work-around software that would be both time and resource consuming. The provision of non-integrated separate data layers offers the user more direct access to feature information by subject. Since current public domain GIS software utilizes this approach of layering spatial data, the non-integrated TTD is more readily usable within these requirements.

Recommendations:

1) The Naval DMAP recommends that DMA conduct an in-depth evaluation of the feasibility of transferring TTD within the ISO-8211 exchange specification. This evaluation should examine the benefits and disadvantages such a transfer mechanism offers to the general DoD user. If transfer continues in its present form, DMAP recommends that subsequent prototype and production data sets include a copy of the original non-ISO-8211 data files or generic software routines which allow the user to recover the data to its original specification form. This latter option was recently utilized in the delivery of a World Vector Shoreline Prototype and has proven to be of great value to naval applications.

2) DMAP recommends that DMA investigate methods of data compression of the TTD to facilitate data handling and access. Many naval applications for TTD will utilize a low-end platform, i. e., Z-248, and will be severely limited by TTD's current size. Use of compression routines to decrease file sizes would support increased access times, as well as other data handling operations. In addition, an examination of the benefits of transferring TTD as binary data could further support the optimization of this product.

3) DMAP recommends that DMA deliver the TTD in the non-integrated format to facilitate user access of the data by decreasing the amount of overhead data the user is required to handle. Currently, no naval systems are capable of utilizing the integrated data, and all applications would require development of additional query software to either bypass or make use of this integration.

Phase II Evaluation:

The Naval DMAP will continue its evaluation of the TTD prototype throughout Phase II of ETL's evaluation process. DMAP will work closely with other Navy Laboratories and U. S. Marine Corps to insure that full Naval requirements for this tactical data product are fully identified and properly addressed.

DMAP support will be provided to this effort through continued participation in Technical Exchange Meetings and DoD symposia, i. e., DMASC Symposium. DMAP will continue to implement TTD within NORDA's specified computer environments and will also offer assistance to the Marine Corps and Navy Labs who utilize the data. Once the data are implemented within these environments, DMAP will assist MCRDAC and NCEL in determining the TTD capability for meeting naval digital terrain information requirements. DMAP will develop visual demonstration routines that show ways to use TTD for naval applications and to aid in determining its effectiveness and deficiencies. These routines will be made available to other labs and to DMA's Warrior Support Center to further publicize naval requirements of the TTD.

Conclusion:

The U. S. Navy and the U. S. Marine Corps are dedicated to utilizing the TTD in support of naval requirements for digital terrain information. The coordinated development and evaluation of this standard digital MC&G product by DMA and the Services is to be commended. This unified approach to evaluating the TTD prototype is providing valuable information necessary to ensure the Services' optimum use of this product. Likewise, the efforts of the U. S. Army, ETL, Concepts and Analysis Division to coordinate the Services' examination of TTD are to be commended. The ideas presented by these organizations are serving to improve the usability of this product, and to ultimately increase the Services' ability to utilize digital MC&G information to complete their respective missions.

The Navy and the Marine Corps have identified and stated direct requirements for the TTD, and have specified improvements needed to increase the products usability for naval terrain analysis applications. The Naval DMAP believes that the recommendations made within this report will greatly improve the Navy's utilization of this digital product. We fully recognize DMA's mission to provide a TTD product that most closely supports the needs and requirements of all the services. DMAP will continue to support these efforts by insuring that the digital terrain information needs of the Navy and Marine Corps have been properly identified and addressed.

Appendix A: TTD Applications Matrix

XII. Appendix A

USER EVALUATION MATRIX -- TTD THEMES

THEME	RANKING
SURFACE CONFIG. (SLOPE)	1
SURFACE MATERIALS (SOILS)	3
VEGETATION	4
OBSTACLES	5
SURFACE DRAINAGE	2
URBAN AREAS	7
TRANSPORTATION	6
SPECIAL FEATURES from 1:50,000 topographic line maps and combat charts	8

Please rank the above themes with the numbers 1 through 8 in order of importance based upon your specific system/activity requirements. We prefer that numbers be used only once. However, if two or more themes are equally important to your system/activity, then the same number may be repeated so as to more accurately portray the needs of your system.

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The Tactical Terrain Data (TTD) will be utilized by the U.S. Navy and the U.S. Marine Corps to support various tactical terrain systems and applications, including Mission Planning for Strike Warfare, Amphibious Area Land Management, Communications for Command and Control, Intelligence Data Fusion, and Maneuvering and Fire Support for Command and Control. The Marine Corps will depend directly upon TTD for enhancement of intelligence information to support battlefield operations. The Navy will utilize the TTD for support of amphibious and near-shore operations, as well as facilities engineering and management.

This report concentrates upon examination of the TTD for its data content, accuracy, resolution, and structure with reference to stated Navy/Marine Corps digital terrain information requirements.

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